REMARKS

Applicants wish to express sincere thanks to the Examiner for a thorough examination of this application. Claims 6, 7, 12, 19, 20 and 25 have been amended to put those claims in independent form to obviate the objection to allowable subject matter. These claims therefore should be allowed and removed from issue. Applicants also respectfully submit that Claims 1-5, 8-11, 13-18, 21-24, and 26 should also be allowed in view of the following submission, or otherwise put in condition for appeal.

Claims 1-5, 8-11, 13-18, 21-24, and 26 have been rejected under 35 U.S.C. § 102(b) as being anticipated by Kumai, et al. U.S. Patent No. 4,073,643. However, these claims are directed to a method making thin steel strip wholly different from the method of making steel disclosed in the Kumai '643 patent. The '643 patent discloses a method for production of continuously cast steel slab for use in manufacturing steel sheet having excellent workability by lowering the silicon (Si) level to less than 0.02% Si. The '643 patent teaches that this method is provided by first producing steel with a "blowing-off" oxygen level between 600 and 1600 ppm in the finished steel in a converter. As the '643 patent specifically instructs:

> "As noted, it is an important object of the present invention to improve the workability of both hot and cold rolled steel sheets by lowering the silicon content to less than 0.02%. For this purpose, it is essential that the steel be blown to an oxygen content from about 600 to 1600 ppm. This relatively high oxygen content is maintained for the specific object of lowering the silicon content.

'643 patent, Col. 7, ll. 50-57.

The molten steel, with an extremely reduced silicon content in the converter, is then tapped into a ladle "where required amounts of low-carbon Fe-Mn, high carbon Fe-Mn, and carbon are added," and the molten steel is subjected to vacuum degassing treatment to reduce both the carbon and oxygen content of the molten steel. '643 patent, col. 7, ll. 58-68. During vacuum degassing, the carbon content of the steel is reduced to less than 0.020%. *Id.* "Al is added for deoxidation to such a degree that blow holes, etc. do not occur during the continuous casting, i.e., until the free oxygen content is lowered to 150 ppm or less." '643 patent, col. 8, ll. 1-4. Alternatively, Al and Ti are used in combination as deoxidizing agents so the soluble Al levels are not more than 0.005% to

maintain the grain structure of the steel. '643 patent, col.8, ll. 6-24.

The molten steel thus prepared is then "continuously slab cast" by "a conventional method." '643 patent, col. 2, l. 14, col. 3, l. 13, col. 8, l. 26. The '643 patent does not describe the thickness of as-cast steel slabs, or the conventional continuous slab casting methods used in 1976 when the '643 patent was filed. The '643 patent states only that the steels in Table 4, which are the focus of the present Examiner's rejection, were made by "[t]he molten steel thus obtained ... cast by a continuous slab casting machine." '643 patent, col. 9, ll. 4-6.

However, the design of a continuous slab casting machine and the thickness of the cast slabs that are produced by this method is well known. As shown by Chapter 15, entitled "The Design of Flat and Long Products Casters," of the Casting Volume of *The Making, Shaping and Treating of Steel* (11th edition), the molten steel is poured from a ladle into a tundish, and then through a submerged entry nozzle into a mold where the steel is moved from a downward vertical direction to a horizontal direction as the molten steel cools where the cast slab emerges from the mold. This is shown in Figure 15.4 of Chapter 15. The design of the continuous casting method is also shown by Figure 6.1 of Chapter 5 of Casting Volume of *The Making, Shaping and Treating of Steel.* Copies of Chapter 15 and Figure 6.1 of Chapter 5 of the Casting Volume of *The Making, Shaping and Treating of Steel* are attached as Addendum A hereto. Further, the thicknesses of cast slabs in thick slabs are 7-12 inches, in medium slabs are 4 ¼ -7 inches, in medium thin slabs are 2 ¾ - 4 ¼ inches, and in thin slabs of 1 ½ - 2 ¾ inches (with the thin slabs developed after 1976). See Figure 15.2 of Addendum A hereto.

Accordingly, there is not in the method of continuous slab casting described in the Kumai '643 patent any disclosure, or even suggestions, of **any** of the specified elements of the presently claimed method set forth in independent claim 1(and its dependent claims 2-5, 8-11 and 13):

> a. assembling a pair of cooled casting rolls having a nip between them and with confining closures adjacent the ends of the nip;
>
> b. introducing molten low carbon steel having a total oxygen content of at least 100 ppm and a free oxygen content between 30 and 50 ppm between the pair of casting rolls to form a casting pool between the casting

rolls;

c. counter rotating the casting rolls and solidifying the molten steel to form metal shells on the surfaces of the casting rolls with levels of oxide inclusions reflected by the total oxygen content of the molten steel to promote the formation of thin steel strip; and

d. forming solidified thin steel strip through the nip between the casting rolls from said solidified shells.

Similarly, there is not in the method of continuous slab casting described in the '643 patent any disclosure, or even suggestions, of **any** of the specified elements of the presently claimed method set forth in independent claim 14 (and its dependent claims 15-18, 21-24 and 26):

a. assembling a pair of cooled casting rolls having a nip between them and with confining closures adjacent the ends of the nip;

b. introducing molten low carbon steel having a total oxygen content of at least 70 ppm and a free oxygen content between 20 and 60 ppm between the pair of casting rolls to form a casting pool between the casting rolls;

c. counter rotating the casting rolls and solidifying the molten steel to form metal shells on the surfaces of the casting rolls with levels of oxide inclusions reflected by the total oxygen content of the molten steel to promote the formation of thin steel strip; and

d. forming solidified thin steel strip through the nip between the casting rolls from said solidified shells.

Specifically, Kumai et al. '643 does not disclose **any of the following:**

a. assembling a pair of cooled casting rolls having a nip between them and with confining closures adjacent the ends of the nip;

b. introducing molten low carbon steel having a total oxygen content of **[any amount]** and a free oxygen content between **[any amounts]** between the pair of casting rolls to form a casting pool between the casting rolls;

c. counter rotating the casting rolls and solidifying the molten steel to form metal shells on the surfaces of the casting rolls with levels of oxide inclusions reflected by the total oxygen content of the molten steel to promote the formation of thin steel strip; **[or]**

d. forming solidified thin steel strip through the nip

between the casting rolls from said solidified shells.

The rejection focuses on Table 4 and particularly Sample V which discloses a steel with T-O (total oxygen) of 210 ppm and F-O (free oxygen) of 35 ppm. However, the presently claimed invention of claims 1-26 is a **method** of making thin cast steel strip, and not the composition that is produced. The rejection states that "Kumai et al. discloses a method of thin cast strip (page 2);" however, Kumai et al. discloses making a continuously cast slab **and** then hot rolling and cold rolling with a large reduction to form the cast strip. This is plainly **not** directed to the disclosed invention of the presently claimed subject matter. Kumai et al. clearly does not disclose an as-cast thin strip as specified by the claimed present method.

It is fundamental to sustain a §102(b) rejection there must be found within the four corners of one reference, either explicitly or inherently, a complete disclosure of each and every element of the claimed invention. MPEP § 2131 ("A claim is anticipated only if each and every element as set forth in the claim is found, either expressly or inherently described, in a single reference."). Plainly, there is not disclosed within the Kumai et al. '643 patent of **any** of elements a, b, c or d of independent claims 1 and 14, **let alone a full disclosure of all of these elements**. Indeed, even the lower of the free oxygen content in Kumai et al. is not for the same purpose as in the present invention. In Kumai et al., the lowering of the oxygen content is to avoid blow holes adversely effecting the continuous slab cast operation caused by excessive oxygen in the steel. '643 patent, col. 1, ll.29-34, col. 8, ll. 1-4. By contrast, in the presently claimed method, free oxygen content (as well as total oxygen content) is controlled within specified parameters to improve heat transfer between the casting rolls and the molten steel in the casting pool. There is no disclosure in the '643 patent that even addresses this problem, let alone disclose or suggest that specific parameters found by the presently claimed subject matter to solve this problem. Where as here, there is evidence of unexpected results within the claimed narrow range, "the narrow range is not disclosed with 'sufficient specificity' to constitute anticipation of the claims." MPEP § 2131.03.

In short, there is no teaching in the '643 patent which discloses the method of making the presently claimed method. Accordingly, applicants respectfully request that claims 1-26 be allowed, and the application be passed to issue. Applicants also note that

Claims 1-13 were already previously allowed by the Examiner in the parent application, of which the present application is a continuation-in-part.

Respectfully submitted,

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Chapter 15

The Design of Flat and Long Products Casters

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15.1 Introduction

The last two decades of the twentieth century saw a dramatic advance in the design of continuous casting machines. In that time, the design capacity of a typical continuous casting strand virtually doubled, yet the capital investment cost did not increase in the same way, which means that the real investment cost per ton of capacity declined.

This improvement was achieved due to a whole range of factors, including:

- An increased process understanding.
- The application of newer and advanced materials such as coatings for molds and rolls.
- The increased reliability of standard proprietary components such as bearings and electrical control equipment.
- Increased automation by the application of many more sensors, actuators, control models and software.
- Attention to the elimination/reduction of casting interruptions.
- The application of more efficient designs due to the use of more sophisticated and rigorous design methods such as finite element (FE) and computational fluid dynamics (CFD) analysis. Such progress has only been possible due to the improvement in computing power.

One of the factors in increasing capacity has been the gradual increase in casting speeds, this in turn has led to the possibility to reduce the number of strands for a given production requirement. Today, for instance, a single-strand slab caster is applied where a two-strand caster was applied in the early days; billet/bloom machines also generally have fewer strands. Reducing strands reduces not only capital costs but also operational costs.

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The continuous casting process, being the liquid-to-solid phase change operation, is the pivotal step in achieving good quality steel processing. Continuous casting machine design is an arena where the various disciplines of metallurgy, mechanical, electrical, control and fluids engineering have to collaborate perhaps more closely than any other in the steel processing route so that the outcome may be successful. Many of the major technologies resulting from those disciplines are embodied in today's sophisticated casters.

Since the early industrialization of continuous casting, there has been a gradual proliferation of machine types tailored to serve particular end uses. This makes continuous casting design all the more varied and exciting.

This chapter deals mainly with continuous casting machine design in relation to conventional thick/medium slab casting and bloom/billet casting. Much of what is described relates to some extent to other nonsynchronous casting processes (those where the mold, although oscillating, is on average stationary in relation to the moving strand) such as thinner slab casting. It does not relate to the synchronous strip casting process where rotating mold rolls are applied.

15.2 Types and Anatomy of Continuous Casting Machines

15.2.1 Types of Casting Machines

Over recent years, the number of different types of continuous casting machines has proliferated as the technology has been applied in new areas that in turn address specific markets.

It is a simple matter to differentiate between flat products, which are derived from slabs, and long products, which are derived from bloom and billets. A width-to-thickness aspect ratio of 2.5 to 1 could be taken as the division between flat and long products.

For bloom and billet casting, there is the range of rectangular/square sections, as shown in Fig. 15.1, as well as beam blanks, which are also shown. Additionally, rounds can replace the squares,

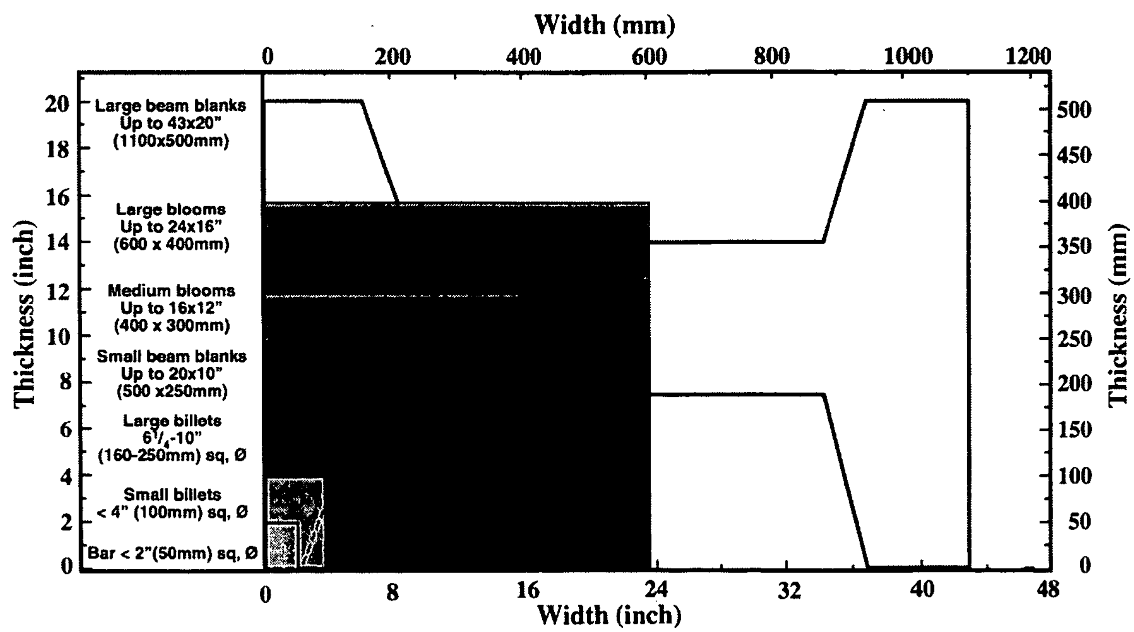

Fig. 15.1 Range of long product cast section sizes.

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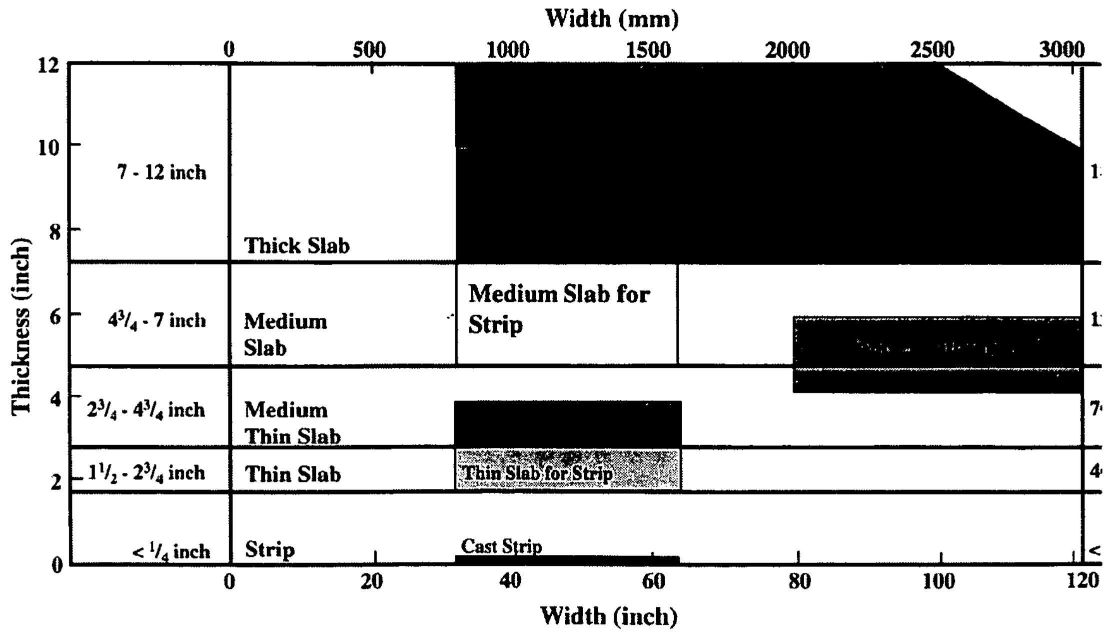

Fig. 15.2 Range of flat product cast slab section sizes.

and there is also a niche for low-volume casting of very small rods and wire. While a large bloom caster can look very different in scale to a small billet caster, the general principles still apply.

For slab casting, the technology has expanded to nearer net shape areas such as thin slab casting, wide plate grade casting and the newly emerging strip casting (see Fig. 15.2).

In addition to dedicated long or flat products casters, combination casters give operators an extra degree of flexibility. In these cases, long products and/or narrower slabs can be cast down slab strands, usually in multiple strands. Fig. 15.3 gives one such example.

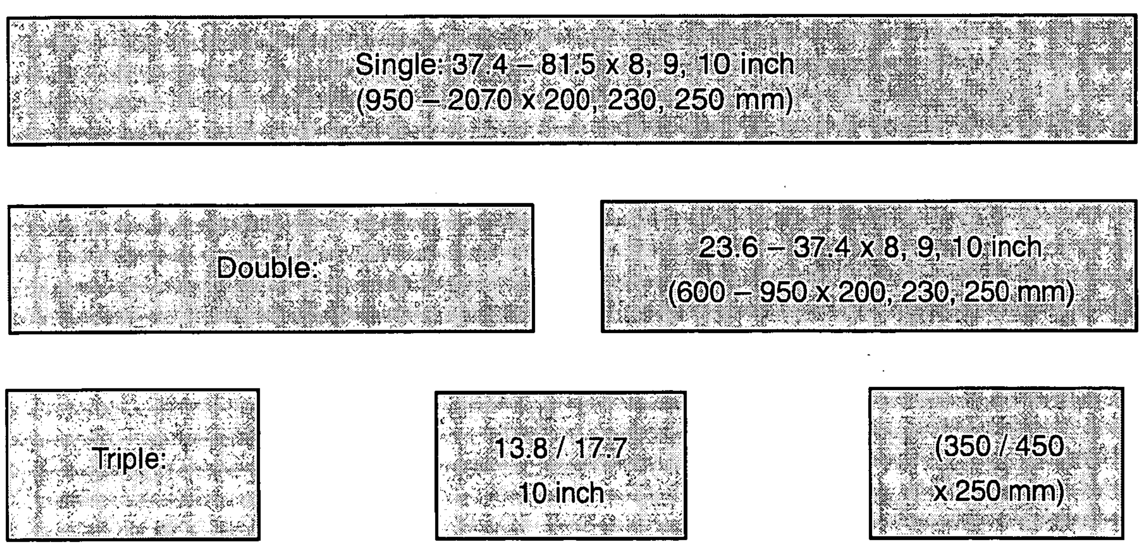

Fig. 15.3 Combination casting at BHP Whyalla.

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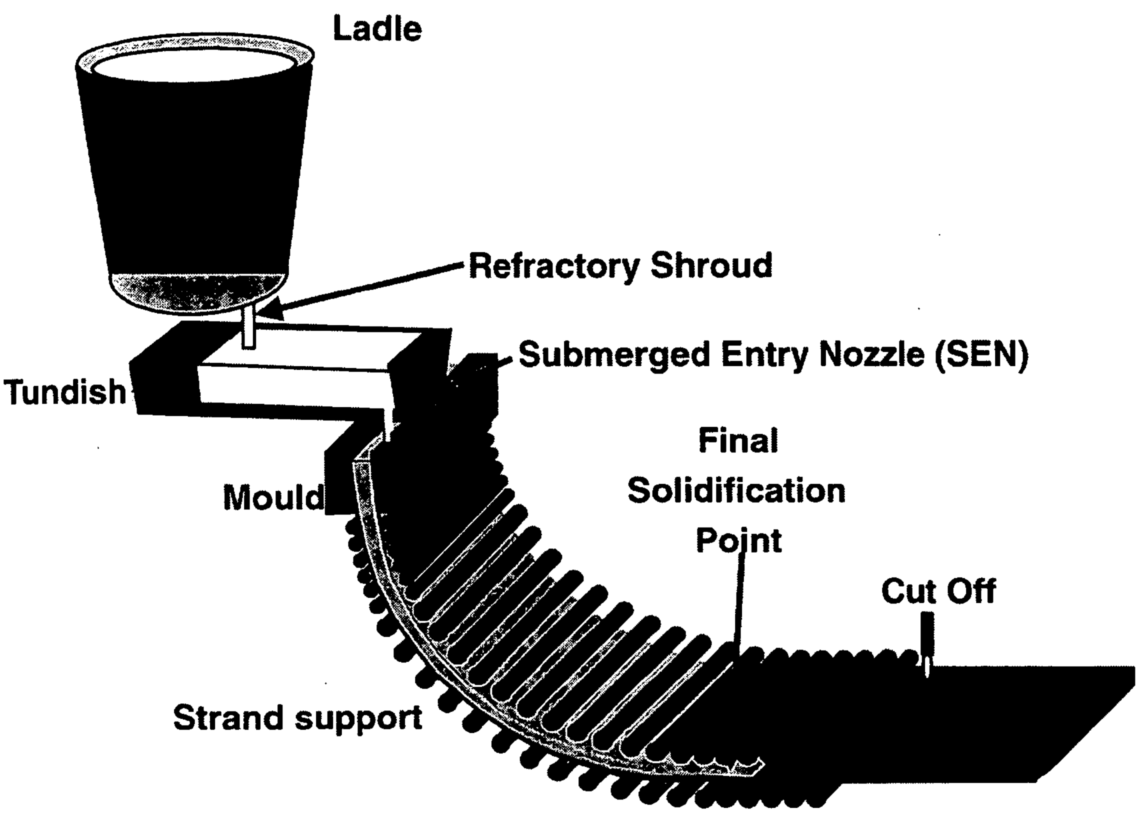

Fig. 15.4 Continuous casting principal parts and process elements.

15.2.2 Basic Caster Process Equipment

The principal parts and process elements of the continuous casting machine are shown in Fig. 15.4 and include the following:

- Ladle: Batch supply of steel to the caster up to 350 tons at a time.
- Tundish: Reservoir of steel that provides a constant supply of steel to the mold, even during ladle changes.
- Mold: Water cooled copper plates that dictate the size and shape of the product. Solidification in the mold is often referred to as primary solidification.
- Strand Support and Cooling: Rolls that support and sprays that cool the solidifying shell and maintain product shape by resisting ferrostatic pressure (that is, the pressure due to the head of liquid steel in the strand). Solidification in this region is often referred to as secondary solidification.
- Final Solidification Point: Point at which the very center of the cast product finally goes fully solid.

15.2.3 Continuous Casting Machine Anatomy

A more detailed anatomy of the continuous casting machine is shown for billet casting in Fig. 15.5, and slab casting in Fig. 15.6.

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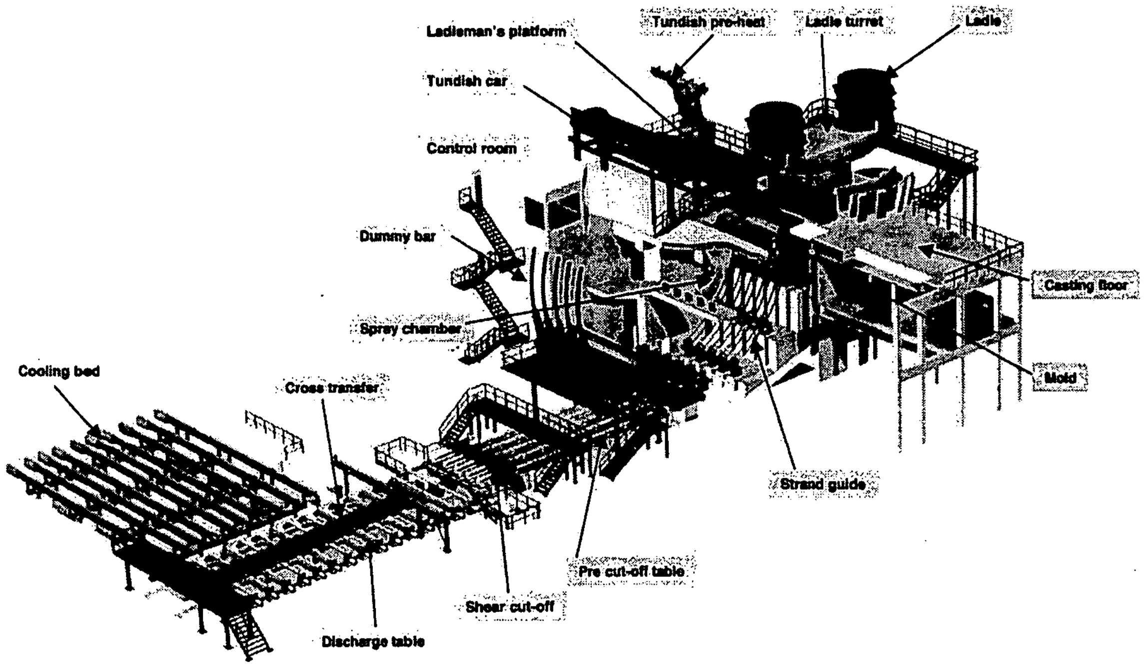

Fig. 15.5 Billet casting machine anatomy.

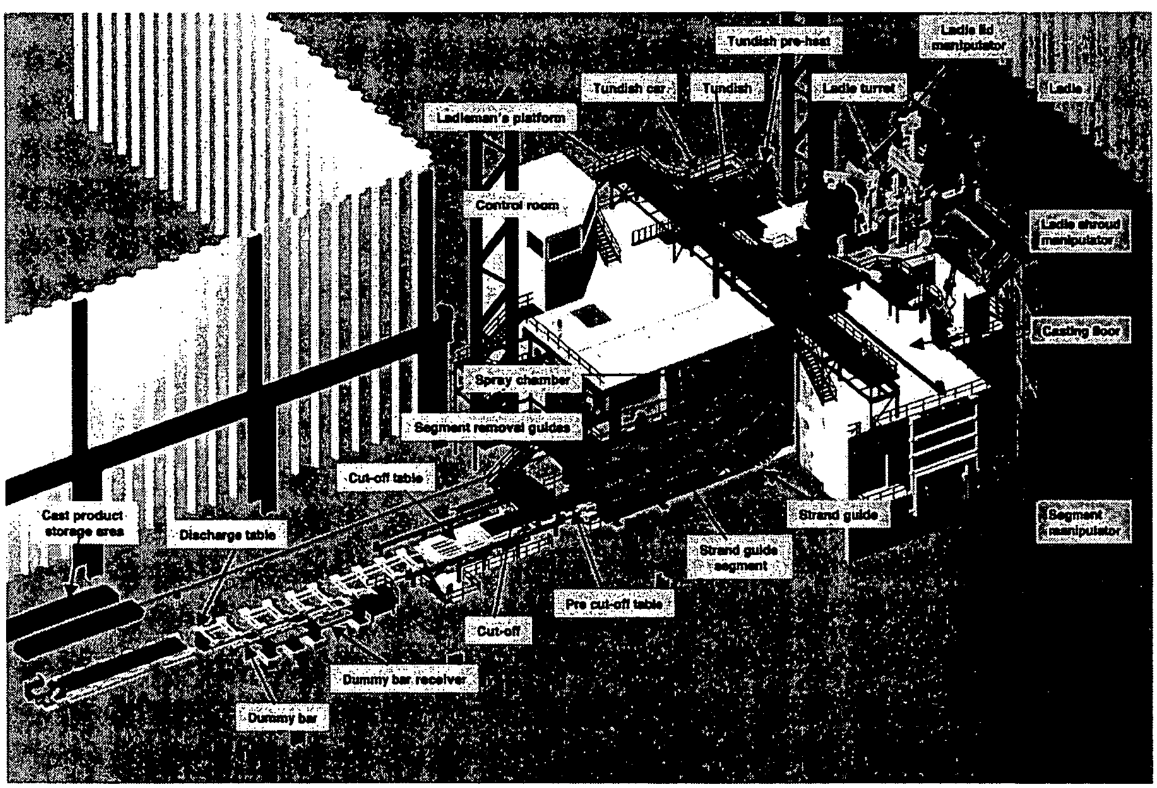

Fig. 15.6 Slab casting machine anatomy.

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Chapter 5

Modeling of Continuous Casting

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The high cost of empirical investigation in an operating steel plant makes it prudent to use all available tools in designing, troubleshooting and optimizing the process. Physical modeling, such as using water to simulate molten steel, enables significant insights into the flow behavior of liquid steel processes. The complexity of the continuous casting process and the phenomena which govern it, illustrated in Figs. 5.1 and 5.2, make it difficult to model. However, with the increasing

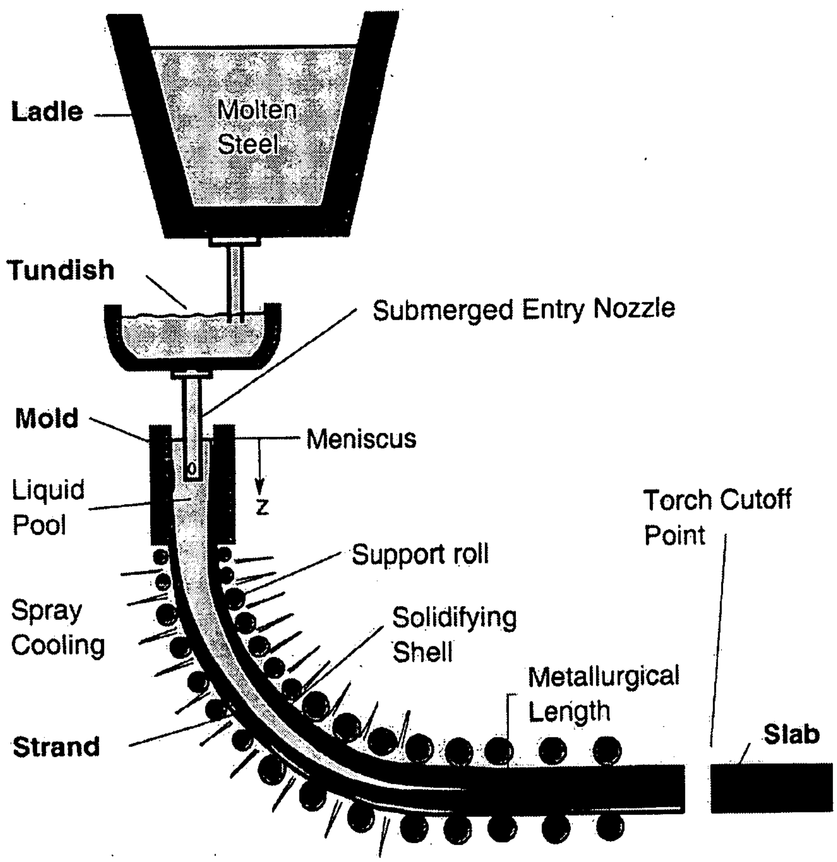

Fig. 6.1 Schematic of continuous casting process.

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